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ABSTRACT

Reported is one of a series of investigations of the Project on an Information Memory Model. This study was done to test an information memory model for identifying the unit of information structure involved in task cognitions by humans. Four groups of 30 randomly selected subjects (ages 7, 9, 11 and 15 years) performed a sorting task of 14 geometric figures. They then recalled the properties of color, shape and identity numbers of figures in spatial locations, corresponding to the display of figures in the passive learning session. As the age of subjects increased, there were more set elements constructed in the figural sorting task but the increase was not significantly greater until done by the 15-year-old subjects who, incidently, had the lowest average intelligence quotient. This indicated that the increased cognition level obtained was not specifically a function of intelligence. One general conclusion was one which alludes to a Piagetian interpretation of mental maturation. The experimental age groups encompassed "early" and "late" stages of concrete and formal operations. (Author/PEB)

INFORMATION MEMORY PROCESSING AND RETRIEVAL: RELATIONSHIPS OF THE INTELLECT WITH THE PROCESSING OF A LEARNING AND COGNITION TASK

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Introduction.

Humans differ in their ability to learn and to have related cognitions. It is believed this is due to the age and intelligence of humans. The advancement of research discovery has established interactions between the age and intellect variables. Some of this discovery has been due to more clarity in describing how humans process ordinary information in learning and cognition tasks (1). Other changes have been the attempt to reinterpret theories of learning in terms of information processing. Piaget has recently made two references (2,3) to the information processing issue in his theory of learning.

Do humans process information in doing a learning task? The evidence of research study indicates they do, and that it can be described. Deutsch (4), by observing external human behavior, found that tonal discriminations are arranged in the memory store in a logarithmic fashion. Callaway and Harris (5) recently reported that electroencephalograph data for transmission activity between cortical areas can be measured with information calculations. Moser and others (6,7,8) have reported findings of information processing of learning and cognition tasks measured by the coding of human behavior data.

Purpose of the Problem.

The study was done to examine the question of how the intelligence of humans is related to the information processed in a learning task. In addition, groups of subjects of different ages were used in the experiment to find out the effect of age in an analysis of the question.

When it is assumed that information is processed in a learning task, the test of validity could be the way in which the information is related to a cognition product. The learning task in the experiment was designed for an immediate recall to determine the plausibility of the assumption.

The research questions were studied by using information measures developed by C. Shannon (9) and Moser (10). The potential for a successful solution of the research questions was thus based on the assumption that human behaviors are Markovian and that the quality of them could be quantified in a logarithmic description.

Procedure.

Four groups of 30 randomly selected subjects aged seven, nine, eleven and fifteen years were drawn from suburban schools in Western Pennsylvania. The groups of children did a 15 minute sorting task and a five minute immediate recall of the figures. The task was displayed on an overhead projector. There were 14 figures of squares, circles, and triangles, numbered randomly from 1-19. They were colored either blue, black, red or green. The subjects classified the figures into sets of three or more elements and gave reasons for each set formation. Elements were recorded by the identity numbers of the figures. The recall task was of subjects recalling the location of the 14 figures and the color and number properties of each figure. The recall scores were obtained by a point system for correct location and assignment of properties. The maximum possible score was 42 points.

The set formation elements were entered into a matrix and treated for information measures. Power tests of a sample of matrices indicated they were all Markovian. Seventeen original matrix and nine steady state information measure values were obtained from each subjects' data matrix.

Four useful information measures and two information process measures were selected for the data analysis. The two original matrix useful information measures were LTM:M^1 and % LTM:M^1(5). The LTM:M^1 measure is expressed as REAL:M^1-CODE, and % LTM:M^1 as LTM:M^1/REAL:M^1. The steady state matrix useful information measures were REAL:SS and % REAL:SS (5). The REAL:SS measure is expressed as H (Y) SS - H (X) M^1, and % REAL:SS as REAL:SS/H (X,Y) SS. The two process measures were % CODE, expressed as CODE/H (X) and % REAL:M^1 which is expressed as REAL:M^1/H (X,Y) M^1.

A seventh information measure was studied for behavior profiles of the subjects doing the task. Moser has reported (10) NOISE:X:M^1 is an indicator of the task being treated as one of problem solving or memory recall.

The t-test was used to test for significance of differences between groups, regarding behaviors and information measures. Linear regression treatments were done to establish levels of relationship between the variables. Trend analysis (11) was done then to measure degrees of dependence between the variables at various levels of behavior.

Results.

The statistics of the characteristics of the four age groups, listed in Table 1, show that the learning tasks were done differently. Figure I shows the results of t-tests for group characteristics. Older subjects tended to write more set elements (listed as messages) in set formations. The tendency was that 11 year old subjects wrote more elements than seven year old subjects but fewer than subjects aged fifteen years. The average recall score did not significantly increase until that obtained by subjects the age of fifteen years.

The average group intelligence quotients, shown in Table 1, were found to range from 104 to 115. The 104 average intelligence quotient of the 15 year old group of children was significantly less than that of the seven and eleven year old groups. There were no other significant differences for intelligence quotient between the other age groups.

There was a trend in the average values of information and information rates processed during the practice learning task. The groups of children aged 7 and 11 years tended to process more information than those groups of children aged 9 and 15 years. An exception was the % LTM:M^1 measure which was at rates not significantly different for most age groups. The 11 year old group of subjects processed significantly more LTM:M^1 than any other age group.

The same trend of age groups was found for the level of NOISE:X:M^1 information measure. The seven and eleven year old subjects had 29.44% and 32.77% levels of NOISE:X. The nine and fifteen year old groups had messages of 42.11% and 44.54% NOISE:X. A t-test analysis of these levels showed no significant

TABLE 1

Characteristics of Age Groups and Task Processing,
by Subjects Aged 7, 9, 11 and 15 Years

Characteristic	7 years		9 years		11 years		15 years	
	$\bar{X}$	Var.	$\bar{X}$	Var.	$\bar{X}$	Var.	$\bar{X}$	Var.
Practice Messages	33.93	2.75	56.83	3.41	47.57	4.20	67.20	5.07
Recall Score	9.77	.88	11.73	.62	12.13	.93	15.57	1.24
Intelligence Quotient	115.00	2.03	110.20	1.97	111.13	2.11	104.43	2.21
% CODE	.6889	.0238	.5527	.0175	.6340	.0193	.5270	.0202
% REAL:M[1]	.5496	.0260	.4059	.0158	.5000	.0225	.3836	.0182
LTM:M[1]	.0750[a]	.0159	.0963[a]	.0116	.1805[a]	.0307	.1017[a]	.0160
% LTM:M[1]	.0357	.0075	.0489	.0071	.0717	.0121	.0535	.0093
NOISE:X:M[1]	.2944	.0222	.4211	.0158	.3277	.0220	.4454	.0180
REAL:SS	.2921[a]	.0386	.1749[a]	.0310	.2084[a]	.0353	.0973[a]	.0220
% REAL:SS	.0424	.0059	.0244	.0045	.0316	.0055	.0132	.0031
Shipley Abstract Reasoning					15.31	2.33	16.04	2.02

[a]To be read as a bit value.

FIGURE I

Comparison of Significant Differences of Characteristics, by Age Groups

Characteristic	Age Groups (in Years)					
	7-9	7-11	7-15	9-11	9-15	11-15 years
Practice Messages	9[a]	11	15			15
Recall Score			15		15	15
Intelligence Quotient			7			11
% CODE	7		7	11		11
% REAL:M[1]	7		7	11		11
LTM:M[1]		11		11		11
% LTM:M[1]						
REAL:SS	7		7		9	11
% REAL:SS	7		7		9	11
ENCODER	9	11	15			
PROCESSOR	9	11	15			
NOISE:X:M[1]	9		15	9		15
M-Unit					15	

[a] To be read that a significant difference (t-test) in messages processed in practice learning occurred, with the nine year old group having the greater number of messages than processed by the seven year old group of subjects.

differences of information spuriousness within these two sets of age groups, but that the levels of NOISE:X between the sets were significantly different. According to Moser (10), both groups were doing the tasks in a problem solving mode, but the nine and fifteen year old groups of subjects tended to regard it as a higher level problem.

The recall scores of the subjects were regarded as levels of cognition for the sorting task which preceded it. An algorithm was developed to describe a possible pathway of memory information processing for the cognition levels of children. The encoding process algorithm was used to define the amount of useful information available for each item retrieved in the cognition. The basic premise was that the messages in the sorting task each carried a certain amount of useful information as $LTM:M^1$ and REAL:SS. The message carriers were processed by % CODE, for the steady state matrix, and the % $REAL:M^1$ measure for original matrix condition. The message premise was then used as it had been hypothesized by C. Shannon (9).

The algorithm equations for treating the data of each subject was:

a) (Messages) (% CODE) = ENCODER
b) (ENCODER) (Steady State Useful Information) = information retrievable
c) (Messages) (% $REAL:M1$) = PROCESSOR
d) (PROCESSOR) (original matrix useful information) = information retrievable
e) Information retrievable of b+d = retrieved information messages for cognition

The equations were done for a sum equal to initial recall for each subject. The results, shown in Table 2, were ascertained to estimate the degree to which the obtained recall level approximated the actual recall score of each subject. It was found that the treatment accounted for an average 95.8 percent of the recall scores of seven year old subjects and an average of 97.1 percent of the scores obtained by 11 year old children. However, the algorithmically obtained recall scores accounted for only 77.0 percent and 51.0 percent of the scores of the 9 and 15 year old subjects. A second treatment was done for these two age groups. The rationale was that these subjects processed an association recall pathway in addition to the initial retrieval pathway. The encoder or processor, % CODE and % $REAL:M^1$, was used with the choice being the age group measure. This treatment was not found necessary for nine of the 11 year old group and six of the subjects of the 15 year old group because their initial recall scores were within five percent of the actual score obtained by them. The initial recall and association recall was summed for an obtained recall for each of the treated data of the other subjects. The average errors of the obtained recall scores were found to be 1.31 percent and 5.02 percent for the 11 and 15 year old groups.

The second algorithmic approach to relate useful information to cognition levels was quite different from the one previously described. The assumption was that the subjects reflected their learning behaviors in the useful information processed during the set formation task. The position was taken that each subject viewed the dimensions of the task as a perceptual field. An examination of the sorting task shows that it has 42 dimensions when interpreted by a method described by Leeuwenberg (12).

The M structure algorithm was expressed as: (Recall Score/42 dimensions) (% CODE). The M structure is an element of useful information theorized from linear analyses of a large number of studies (1). The evidence indicates that the basic unit of useful information stored in the memory is .1548 bit. That unit is changed, under various behavior experiment conditions, by a sub-unit of .0129 bit of information.

The individual scores of the subjects were treated for obtaining three M algorithm values. These were M useful retrieval information, M unit, and increment change, or the difference between .1548 bit and information needed for cognition; as .0129 bit changes. The M useful information is the product stated above. The treatments for each age group are shown in Table 2. The t-tests for the M unit of information, shown in Figure I, showed little difference between the age groups. The only significant difference was that a larger amount of M unit information was needed for obtaining recall scores of the 15 year old group than the 9 year old group of subjects.

The M structure algorithm study revealed three major findings. The first one was that the .1548 M unit was quite viable as a concept. The change for increments of .0129 bit for the four age groups was a minus two percent to plus 25 percent; the greater change being for the 15 year old group of subjects. The second finding was that subjects less than 11 years of age tended to need an average of less one increment of .0129 bit adjustment from the basic value of .1548 bit in order to obtain a recall score of less than two percent error. On the other hand, the two older groups of subjects had cognition levels which needed .0129 bit increments of two or more to obtain recall scores of less than two percent error. Keep in mind that the M structure algorithm operates with the level of cognition for the % CODE or encoder process, and that the dimension of 42 is kept constant. This relationship of variables had a bearing on the amount of useful information needed for obtaining a reliable cognition level for each age group. Thus, the third major finding was that the M useful information generally increased as there was an increase in the age of the children.

Linear analyses were done to determine the relationships of practice messages, immediate recall score, intelligence quotient and the M unit with information measures and encoder-processor algorithm variables. The coefficients of correlation for these relationship tests are shown in Tables 3, 4, 5, and 6, for the respective age groups. The following interpretation of the relationships will refer to all four tables of analysis treatments.

The steady state useful information measure, REAL:SS, was found not to be generally related* to the number of messages processed in doing the sorting task. This relationship changes for 11 year old subjects where it was negatively related to the messages variable. The inverse of REAL:SS was also related for the 11 year old group, as was the case for the group of 15 year old subjects. On the other hand, the other information measures (% CODE, % REAL:M^1, LTM:M^1, and % LTM:M^1) were all related with the messages variable irrespective of the age of the children. It was concluded that the messages concept for the Shannon (9) theorem was validly operating for describing the set formation behaviors of information flow. Furthermore, the relationship was generally one of the original matrix or of short term memory information measures.

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*The term "related" hereafter refers only to significant levels of relationship.

TABLE 2

Characteristics of Cognition Prediction Algorithms, by Age Groups

Characteristic	7 years		9 years		11 years		15 years	
	$\overline{X}$	Var.	$\overline{X}$	Var.	$\overline{X}$	Var.	$\overline{X}$	Var.
A. Message								
Encoder	21.922	1.176	30.018	1.164	28.340	1.872	32.882	1.633
Processor	17.285	1.038	21.849	.839	21.980	1.548	23.682	1.210
M[1] Storage	2.360	.525	3.447	.508	6.725	1.495	4.405	.942
SS Storage	6.900	.912	5.631	1.012	5.786	.880	3.522	.880
Initial Recall	9.360	1.208	9.030	1.206	11.775	1.778	7.936	1.568
Assoc. Recall			2.854	.423			6.852	.874
Obtained Total Recall			11.884	1.094			14.788	1.134
B. Dimension Algorithm								
M Value	.543	1.195	-.200	.644	2.400	1.282	3.033	1.432
M Unit of information	.1604	.0155	.1522	.0083	.1845	.0168	.1939	.0185
M Useful information	.2334	.0207	.2802	.0150	.2892	.0225	.3682	.0295

The linear relationships between information measures and the level of cognition showed a different, but previously observed pattern. The seven and eleven year old groups of subjects were found to be similar in the mode of information processing. Both groups had positive relationships between the inverse of REAL:SS and recall score. The subset of nine and fifteen year old groups of subjects did not show such an apparent pattern similarity. The REAL:SS measure of the nine year old group was negatively related to the cognition level of the immediate recall.

The 15 year old group of subjects did not have any information measures, as shown in Table 6, significantly related with the recall score variable. Recall that both groups had association recall equation steps in the treatment for encoder and processor algorithm. The association recall scores and initial recall scores of both groups were tested for linear relationship with the total recall scores. The initial recall score variable was positively related (.841 for 9 year old and .759 for the 15 year old group) with the REAL:SS measure. The REAL:SS measure was negatively related (-.449 and -.306) to the association recall score variable for each group of subjects.

Linear analyses of the intelligence quotient and information processing showed more involved patterns. None of the information measures, listed in Table 3, for the seven year old group of subjects were significantly related with the intelligence quotient. A search of the previously mentioned information measures involved in the memory model, but not used for primary treatment in the study, revealed an explanation. The H (Y) M^1 measure was found to be related to the recall score (.313), messages processed in the learning task (.363), and intelligence quotient (.314). Furthermore, the H (Y) M^1 measure was positively related to the inverse of REAL:SS (.410). The 11 year old group of subjects had a more direct relationship, with the REAL:SS having a negative relationship with the intelligence quotient.

The nine year old group of children had direct relationships between the intelligence quotient and the number of messages practiced in the sorting task and the level of cognition in the immediate recall. The intelligence quotient was negatively related with the information rate of flow for the processors of the steady state and original matrix conditions, i.e., % CODE and % REAL:M^1. The relationship of intelligence quotient for the 11 year old children was a negative one with REAL:SS, or the useful information of the steady state matrix condition. The 15 year old group of subjects was found to have a pattern of relationships much like that of the nine year old subjects. The intelligence quotient was positively related to the number of messages processed in the practice learning task and negatively related to the information processing rate of flow in both the original and steady state matrix conditions.

Two of the age groups of children also took the Shipley Abstract Reasoning Test. This test has been used to distinguish subjects in the concrete and formal operational levels of mental maturity (13). The 11 year old children had Shipley Test scores directly related to intelligence quotient and indirectly related to the logarithm of the inverse of intelligence quotient (see Table 6). The latter intelligence quotient treatment was not found to be significantly correlated with the Shipley Test score of 15 year old subjects.

TABLE 3

Coefficients of Correlation Between Messages, Recall Level and Intelligence Quotient and Information Flow, by Seven Year Old Children

Characteristic	Practice Messages	Recall Score	Intelligence Quotient	Log$_2$ 1/I.Q.	M-Unit
Practice Messages		.097	.037	-.012	-.206
Recall Score			.090	-.126	.919[a]
Intelligence Quotient					.052
% CODE	-.768[a]	.051	.106	-.148	.409[a]
% REAL:M^1	-.659[a]	.030	.093	-.137	.427[a]
LTM:M^1	.664[a]	.021	.207	-.177	-.111
% LTM:M^1	.730[a]	.001	.073	-.050	-.223
REAL:SS	.011	-.167	.040	-.019	-.233
% REAL:SS	.019	-.170	.035	-.013	-.244
ENCODER	.818[a]	.125	.183	-.173	-.028
Processor	.659[a]	.115	.197	-.194	.051
M-Unit				-.103	
1/REAL:SS	.036	.378[a]	-.004	.013	-.359[b]

[a]Significant at the .05 level (.362).

[b]Significant at the .10 level (.307).

TABLE 4

Coefficients of Correlation Between Messages, Recall Level, and Intelligence Quotient and Information Flow, by Nine Year Old Children

Characteristic	Practice Messages	Recall Score	Intelligence Quotient	Log2 1/I.Q.	M-Unit
Practice Messages		.427[a]	.384[a]	-.352[b]	-.054
Recall Score			.510[a]	-.505[a]	.833[a]
Intelligence Quotient					.230
% CODE	-.806[a]	-.279	-.448[a]	.426[a]	.273
% REAL:M[1]	-.799[a]	-.280	-.468[a]	.447[a]	.261
LTM:M[1]	.645[a]	.251	.051	-.034	-.057
% LTM:M[1]	.621[a]	.207	.135	-.120	-.163
REAL:SS	-.088	-.338[b]	-.201	.196	-.404[a]
% REAL:SS	-.079	-.335[b]	-.200	.196	-.415[a]
ENCODER	.863[a]	.326[b]	.172	-.139	.171
PROCESSOR	.755[a]	.412[a]	.051	-.022	.227
M-Unit				-.244	
1/REAL:SS	.218	.141	-.131	.173	.103

[a]Significant at the .05 level.

[b]Significant at the .10 level.

TABLE 5

Coefficients of Correlation Between Messages, Recall Level, and Intelligence Quotient and Information Flow, by Eleven Year Old Children

Characteristic	Practice Messages	Recall Score	Intelligence Quotient	Log_2 1/I.Q.	M-Unit
Practice Messages		.100	.190	-.198	-.235
Recall Score			.236	-.231	.902[a]
Intelligence Quotient					.176
% CODE	-.776[a]	.092	-.053	.059	.491[a]
% REAL:M^1	-.658[a]	.125	-.035	.030	.520[a]
LTM:M^1	.366[a]	.074	-.095	.065	.035
% LTM:M^1	.457[a]	.059	-.135	.103	-.021
REAL:SS	-.475[a]	-.150	-.349[b]	.348[b]	.013
% REAL:SS	-.517[a]	.011	-.252	.250	.196
ENCODER	.949[a]	.076	.180	-.195	-.167
PROCESSOR	.829[a]	.093	.135	-.166	-.058
M-Unit				-.170	
1/REAL:SS	.499[a]	.311[b]	.286	-.270	.008
Shipley Abstract Reasoning	.206	.217	.460[a]	-.476[a]	.140

[a]Significant at the .05 level.
[b]Significant at the .10 level.

TABLE 6

Coefficients of Correlation Between Messages, Recall Level, and Intelligence Quotient and Information Flow, by Fifteen Year Old Children

Characteristic	Practice Messages	Recall Score	Intelligence Quotient	Log_2 1/I.Q.	M-Unit
Practice Messages		-.008	.514[a]	-.499[a]	-.338[b]
Recall Score			.213	-.221	.910[a]
Intelligence Quotient					.035
% CODE	-.854[a]	-.004	-.355[b]	.351[b]	.379[a]
% REAL:M[1]	-.785[a]	.004	-.314[b]	.309[b]	.372[a]
LTM:M[1]	.807[a]	.095	.325[b]	-.319[b]	-.063
% LTM:M[1]	.816[a]	.076	.312[b]	-.307[b]	-.197
REAL:SS	.086	.058	-.220	.218	-.080
% REAL:SS	.096	.061	-.225	.212	-.080
ENCODER	.916[a]	.004	.505[a]	-.486[a]	-.243
PROCESSOR	.859[a]	.028	.478[a]	-.453[a]	-.173
M-Unit				-.047	
1/REAL:SS	.383[a]	-.096	.275	-.251	-.111
Shipley Abstract Reasoning	.238	.253	.095	-.610[a]	.205

[a]Significant at the .05 level.
[b]Significant at the .10 level.

The messages or elements of sets written by subjects in the practice learning task are related to some of the information measures as the messages are used to construct the matrix from which the measures are calculated. However, as seen in Tables 3-6, this relationship was linear only for original matrix information measures for all ages of children. The steady state measure REAL:SS was negatively related to the messages processed by 11 year old children. The inverse of REAL:SS was found to be positively related to the messages processed by children aged 11 and 15 years.

The question raised was what was the role of information measures on an intermeasure basis? The linear analysis of this relationship for age groups is shown in Table 7. Keeping in mind that the information measures for all behavior data of all age groups were calculated through the same equations it was surprising to find not all age groups had the same pattern of significant interrelationships.

The % CODE and % REAL:M^1 processor measures were found to be related to "chunked" information (LTM:M^1, % LTM:M^1) for all age groups except those of 11 years. The steady state useful information of 11 year old subjects was positively related to the processors. The "chunking" information measure of the original matrix condition was found related to steady state useful information for subjects aged 7, 11 and 15 years. The linear operator relationship of original matrix measures with steady state useful information was noticeably nonsignificant for nine year old subjects.

The four age groups had pathways of processing information through the learning task messages for cognition in the immediate recall task. The sequence for seven year old subjects was messages, % CODE, REAL:SS, and inversion of REAL:SS, and cognition. The sequence was of two negative operators and a positive linear operator. The nine year old subjects had a direct positive relationship between the learning task messages and cognition. They also had a double negative operator pathway from dimension perceptions through REAL:SS of the learning task and then to cognition. The 11 year old subjects had an information pathway which was the same succession as that for the seven year old group except the operator relationships were all positive. The 15 year old group of children processed learning task messages through LTM:M^1, % CODE, dimension perception, and cognition. The linear relationships were all positive.

The interrelationships between intelligence, messages processed and information flow of the learning task, and the levels of cognition of the immediate recall task prompted a trend analysis. The analysis was done with the intelligence quotient as the dependent variable. The reader should keep in mind that the linear trend analysis would have a 90 percent estimation confidence for subjects of the experiment. It should also be noted that the M unit, being devised for the % CODE measures, was not a primary trend element and was always calculated last in position. The trends are shown in Table 8.

The effect of the intelligence quotient of zero to 170 was not extensive for the recall cognition. The exception was the nine year old group with a range of 22 points of recall. The 7 and 11 year old groups had effect ranges of 2.96 and 2.17 recall points, respectively. Quite uniquely, as intelligence quotient

TABLE 7

Significant Coefficients of Correlation Between Information Measures, by Age Groups[a]

Information Measure	% REAL:M^1	LTM:M^1	% LTM:M^1	REAL:SS	% REAL:SS
% CODE					
7 years	.954	-.382	-.647	-.329	-.357
9 years	.990	-.517	-.644		
11 years	.962			.350	.424
15 years	.985	-.574	-.643		
% REAL:M^1					
7 years			-.474		
9 years		-.405	-.535		
11 years				.396	.446
15 years		-.452	-.519		
LTM:M^1					
7 years			.878		
9 years			.954		
11 years			.974		
15 years			.981	.447	.460
% LTM:M^1					
7 years				.340	.371
9 years					
11 years				.529	.542
15 years					
REAL:SS					
7 years					.997
9 years					.998
11 years					.889
15 years					1.000

[a]Significant coefficients of correlation for .10 level of significance.

increased, the possible linear cognition decreased for 15 year old children. An examination of the linear relationships of the M unit and REAL:SS shifts indicated that an inverse relationship between the intelligence quotient and useful information storage and recall was probably occurring.

The trend for variables changing with an increase of intelligence quotient showed three age-related patterns. The seven year old group had decreases of messages and long term memory (REAL:SS) as intelligence levels increased. The recall score, on the other hand, increased. The 9 and 11 year old groups of subjects showed increases in the messages processed and the level of recall while the REAL:SS decreased. The 15 year old group of subjects had an increase in the messages processed in the learning task, along with an increase in the level of REAL:SS processed per message. At the same time as the intelligence level increased, the amount of cognition would have decreased. Note that the amount of REAL:SS or steady state information decreased per learning task message as the level of intelligence increased for children aged less than 15 years. Considering levels of mental maturation is this a function of the kind of task: a figural classification learning task?

A rather narrow range of M values, $\pm$ .0129 bit, was found to occur for the span of from zero to an intelligence quotient of 170. This finding was obtained by comparing M units, listed in Table 8 with the basic unit of structure of 0.1548 bit. The range of 7 year old children was -2.7 to 1.9, -2.5 to 1.4 for 9 year olds, -.07 to 3.4 for 11 year old children, and +0.62 to +6.7 for the 15 year old children.

The mental maturation levels prescribed by J. Piaget have been translated into a central processor construct by J. Pascual-Leone (14) who independently assigned the letter M to that construct. He postulates an M operator to be of two parts: the size value a, which is an unexplained constant for all ages, and K which is a characteristic quantity for developmental stages. Pascual-Leone's findings indicate the K values for the ages reported in this study would be 3, 4, 5 and 7. The a constant proposed by Pascual-Leone is considered to be three.

The premise explored in this analysis was that the intelligence of humans was inversely related to the M structure of cognition. Evidence that intelligence is possibly a component of structure for cognition is seen in the logarithmic transformations of intelligence, shown in Table 9, as $\log_2 1/I.Q.$ The reader may note how the proposed M unit of .1548 bit is related to the intelligence transform, i.e., at an intelligence quotient level of about 88. Notice too that the direction change of M unit for intelligence by 15 year old subjects approximates that of the intelligence transformation, i.e., .2038: .2281 to .1350: .1628.

The M units for the age groups at each trend position of intelligence quotient was compared for increments of .0129 bit from the M unit of .1548 bit. It can be seen, in Table 9, that subjects aged seven, nine and 11 years had increment ranges which decreased from a 9.2 to an 8.0 value (computed for 7 year olds as -5.7 to +3.5, etc.). The 15 year old group had a small change with a rather constant level from intelligence quotients 60 to 110. It would appear that the 15 year old children, probably being in the formal operation stage, had a constant M structure with respect to intelligence. On the other hand the shift of intelligence for M structure increases as the age of the child decreases.

TABLE 8

Trends of Regression Analysis of the Intelligence Quotient by Age Groups

INTELLIGENCE QUOTIENT	RECALL 7	RECALL 9	RECALL 11	RECALL 15	REAL:SS 7	REAL:SS 9	REAL:SS 11	REAL:SS 15
0	7.33	-5.87	10.40	18.52	.6018	.4472	.8562	-.0533
30	7.97	-1.08	10.87	17.66	.5210	.3656	.6820	-.0093
60	8.60	3.71	11.33	16.80	.4402	.2842	.5080	.0348
70	8.81	5.31	11.49	16.52	.4133	.2570	.4500	.0495
80	9.03	6.91	11.64	16.23	.3863	.2298	.3920	.0642
90	9.24	8.51	11.80	15.96	.3594	.2027	.3340	.0789
100	9.45	10.11	11.95	15.66	.3325	.1755	.2760	.0936
110	9.66	11.70	12.11	15.38	.3055	.1483	.2180	.1083
120	9.87	13.30	12.26	15.09	.2786	.1212	.1600	.1229
140	10.30	14.90	12.57	14.52	.2247	.0668	.0440	.1523
170	10.93	21.29	13.04	13.66	.1439	-.0147	-.1300	.1964

INTELLIGENCE QUOTIENT	M UNIT 7	M UNIT 9	M UNIT 11	M UNIT 15	MESSAGES 7	MESSAGES 9	MESSAGES 11	MESSAGES 15
0	.1199	.1226	.1557	.2421	39.51	-16.65	11.03	-55.45
30	.1304	.1315	.1633	.2281	38.05	3.37	20.85	-20.23
60	.1410	.1403	.1709	.2141	36.60	23.38	30.67	15.01
70	.1446	.1433	.1734	.2095	36.12	30.05	33.94	26.76
80	.1481	.1462	.1760	.2048	35.63	36.73	37.21	38.50
90	.1516	.1492	.1785	.2003	35.15	43.40	40.48	50.25
100	.1551	.1521	.1810	.1954	34.66	50.07	43.75	61.99
110	.1587	.1551	.1835	.1908	34.18	56.74	47.03	73.74
120	.1622	.1580	.1861	.1861	33.69	63.41	50.30	85.49
140	.1693	.1639	.1911	.1768	32.72	76.76	56.84	108.98
170	.1798	.1728	.1987	.1628	31.27	96.77	66.65	144.22

A consideration of when the intelligence effect shifts for an increment addition to the M unit of .1548 bit shows that the intelligence quotient is lower as the age increases. In other words, a zero increment is found at intelligence quotients of 100 for seven year old children, 90 for nine year old children and 60 for 11 year old children. That level never ensued for the 15 year old children. It would appear that intelligence is logarithmically involved with the M structure and the concept presented herein, supports other theories of mental maturation. However, the findings do not confirm the whole number values reported by Pascual-Leone (14).

The relationships between information measures, practice learning messages and levels of cognition were explored by a random search computer program for developing prediction algorithms of recall scores obtained by groups of subjects of particular intelligence quotients. The numerical methods were limited to multiplication and division and the transformation limits were an inverse of an equation element, its base two logarithm or natural number if the element was an existing information measure. The search selection was limited to the % CODE, % REAL:M^1 and REAL:SS measures and the number of messages for the learning task hypothetically done by a group of subjects at the specified intelligence quotient. The objective of the information measure constraint was to construct a model for the processing (% CODE, % REAL:M^1) useful information (REAL:SS) through the long term memory.

Twenty prediction equations were selected, for the 60, 80, 100, 120, and 140 levels of intelligence quotients of hypothetical age groups of 7, 9, 11, and 15 years. The predictions of the twenty levels of cognition, as shown in Figure 2, had a mean error of 3.38 percent (variance of 0.47%). Sixty percent of the predictions contained the product of the messages of the learning task and REAL:SS information. Three-fourths of the equations used the learning messages element. These major findings indicate the search selection by the computer program was not random. This finding is highlighted by the computer command limit to three equation constructions for obtaining the minimum percentage error in predicting the level of cognition.

The proposed algorithms for cognition levels showed a two-dimensional pattern of equation processes. The first one, by age, showed the 15 year old group of subjects had the more "uncommon" equations. The intelligence dimension was from a logarithmic transformation of messages for a ratio of the optimization of useful information: as $\text{Log}_2 A/(D/C)$, by an encoder (C). This "evolved" through a standard REAL:SS per message product optimized by either the basic M unit of .1548 bit to a % REAL:M^1 processor by the average intelligence quotient level of 100. The learning task message equation element was excluded for higher intelligence cognition models, with the useful or REAL:SS information being transformed and optimized by an encoder (% CODE).

The three younger hypothetical groups of subjects showed a trend of transformation algorithmic equations being used at lower than average intelligence levels. This was the case in four-fifths of such kinds of equations, with the exception of the nine year old group of an assumed 140 intelligence quotient. The nine year old group, as found in previous analyses, more closely resembled the 15 year old group in equation constructions. These involved inclusion of the message element in two equations, and three equations of logarithmic and inverse transformations.

TABLE 9

Differences Between M Units and Log_2 Intelligence Quotient for Levels of Intelligence Quotient, in H-Values

Intelligence Quotient	M Values				
	7 yrs.	9 yrs.	11 yrs.	15 yrs.	$Log_2 1/I.Q.$
30	-5.7*	-5.6	-3.1	+1.9	.2038
60	-2.3	-2.2	+0.1	+3.5	.1693
70	-1.9	-1.5	+0.8	+3.5	.1631
80	-0.8	-1.0	+1.4	+3.6	.1582
90	-0.2	-0.4	+1.9	+3.6	.1540
100	-0.4	+0.1	+2.4	+3.5	.1505
110	+0.9	+0.6	+2.8	+3.4	.1475
120	+1.3	+1.0	+3.2	+3.2	.1448
140	+2.2	+1.8	+3.9	+2.8	.1403
170	+3.5	+2.9	+4.9	+2.2	.1350
AVERAGE	-0.34	- .43	+1.83	+3.12	

* To be read that 7 year old children at an I.Q. of 30, had 5.7 values of .0129 bit below the M unit of .1304, as compared to the .2038 bit inverse of I.Q.

The prediction of intelligence level cognitions as presented here, is regarded as quite theoretical. The forecast experiment was done with the major objective of determining whether or not information processing could be used for "explaining" a construct of age-intelligence variations for memory cognition.

FIGURE II

Proposed Cognition Algorithms for Levels of Intelligence, by Age Groups

	Intelligence Quotient Level				
A. Age	60	80	100	120	140
7 yrs.	AD X B	AD X C	Log_2 A/B	AD	AD/C
9 yrs.	AD X C	Log_2A/D	$\frac{1}{D}$ /C	AD/C	$\frac{1}{D}$
11 yrs.	$\frac{1}{D}$ /C	AD	AD	AD/C	AD/B
15 yrs.	Log_2A/(D/C)	AD/.1548	AD/B	$\frac{1}{D/C}$	Nat D/(D/C)
B. Obtained Recall Score					
7 yrs.	8.86	9.48	9.31	9.39	10.67
9 yrs.	3.67	6.81	10.31	13.90	14.97
11 yrs.	10.31	12.24	12.08	12.69	12.00
15 yrs.	17.82	15.97	15.13	15.44	13.85
C. Percent Error					
7 yrs.	2.96	4.98	1.48	4.90	2.36
9 yrs.	1.02	1.45	2.08	4.55	0.47
11 yrs.	9.00	5.17	1.09	3.54	4.53
15 yrs.	6.07	1.60	3.38	2.35	4.61

LEGEND:

A Messages
B % REAL:M[1]
C % CODE
D REAL:SS

Conclusion and Discussion.

This study was done to determine the role of intelligence in cognitions for a figural sorting task processed by subjects aged 7, 9, 11 and 15 years. The basic approach was the use of learning behavior information measures, as linear operators, to describe the ways in which humans conducted the immediate recall task.

The subjects differed as to the amount of set formations in the learning task and in the amount of figures and properties they could recall. The age difference for set formations were not continuous in significant differences for increasing ages. The samples partitioned into differences between seven and eleven year old subjects, as compared to a grouping of nine and fifteen year old subjects. The level of cognition was not found to significantly increase until the recall done by the 15 year old subjects. The intelligence quotient of the 15 year old group of subjects was significantly lower (104) than the averages for seven and eleven year old groups of subjects.

The general conclusion was that, as the age of subjects increased, there were more set elements constructed in the figural sorting task. However, even though a greater amount of recall occurred as age increased, the increase was not significantly greater until done by 15 year old subjects. The fact that the 15 year old subjects had the lowest average intelligence quotient indicates the increased cognition level obtained by them was not specifically a function of intelligence.

The tendency for common behavior traits to be observed occurring with nine and fifteen year old subjects was highlighted by linear regression analyses which showed the amount of learning set elements and level of cognition by nine year old subjects was directly related to the intelligence quotient. The same learning trait occurred for 15 year old subjects. On the other hand, these traits were not found to be significantly related for subjects aged seven or eleven years.

An analysis of the amount of information processed per learning behavior showed the trend previously observed for cognition and practice learning characteristics. The seven and eleven year old subjects had greater amounts of information flow per message. This was a constant trend for encoder and processor memory elements. A contrast was seen in the finding that the nine and fifteen year old subjects had greater levels of NOISE:X per message than those of seven and eleven year old subjects. The conclusion was that seven and eleven year old subjects encoded and processed more information per practice message and maintained a less spurious short term memory channel.

The differences in the amounts of useful information per practice message were not found to have a clear pattern of age segregation. The eleven year old group of subjects had greater levels of chunking, $LTM:M^1$, than processed by other age groups; which did not differ significantly from each other. The steady state useful information, REAL:SS, was processed in larger amounts by subjects aged 7, 9, or 11 years than by the 15 year old subjects.

The general conclusion was one which alludes to a Piagetian interpretation of mental maturation. The experimental age groups encompass "early" and "late" stages of concrete and formal operations. Task perception, NOISE:X and encoding information processes follow that general trend of maturation stage development. On the other hand, the "late" formal stage group of subjects showed a marked change for the storage of long term (steady state condition) memory useful information (REAL:SS).

This conclusion may have two issues of consideration for causal factors. It could be that the task of figural sorting was age-related as to how it was perceived by subjects and that 15 year old (formal operational) subjects differed in their perceptional set. This consideration is seen only in the extent to which long term memory information is processed. The other consideration is that 15 year old subjects processed the task in the described manner because they generally had a lower intelligence.

These considerations were explored by developing forecast algorithms of cognition levels. A message encoding and processing algorithm of long and short term memory information was used to predict recall score of individual subjects. The results were that seven and eleven year old subjects obtained actual cognition levels by an initial recall stage; with prediction errors of less than five percent. The nine and fifteen year old subjects obtained prediction errors of less than five percent only by implementing an association recall equation in the algorithm. This treatment then supported the Piagetian operational stage consideration.

The second algorithm, used to forecast cognition levels, was one which substituted perception dimensions for messages processed in the practice learning task. A unit structure of information concept was used in equations with the % CODE information measure and a dimension constant of 42, or the three properties of shape, color, and number for 14 figures in the sorting task. The M unit was hypothesized to be 0.1548 bit, with increments of 0.0129 bit adjustments; due to the ages of subjects. The increment change unit memory structure for cognitions was found to be less than one-half for seven and nine year old subjects, and to increase to 2.4 and 3.0 units for the older groups of subjects. This pattern indicated the maturation levels of unit structure increments were segregated into concrete and formal operational stages.

With the risk of being tautological in the interpretation of research findings a system of pathways of information flow was developed for the effects of learning experience, cognition and intelligence of the subjects of different ages. The justification for conclusions presented in this manner is supported by Yamane (11) and the fact that the interpretation is made for the direction of dependency between variables.

There were two major pathway loops for information memory processing by the seven year old subjects. The first one was between messages, intelligence and H (Y) M^1. All three were positively related to each other, with H (Y) M^1 being the intermediate element. The H (Y) M^1 measure is the output of the short term memory. The H (Y) M^1 measure was found positively related to the inverse of the useful information (REAL:SS) of the long term memory storage, which in turn was positively related to the level of cognition. The inverse of REAL:SS was negatively related to the M unit structure of the dimension algorithm. The learning messages were positively related to the short term ratio of chunking (% LTM:M^1) which was negatively related to the REAL:SS measure. This loop could serve as a feedback control to effect the amount of REAL:SS, which by decreasing as there was an increase of learning messages would result in a larger inverse REAL:SS and potential of a greater cognition output. The conclusion reached was that early concrete stage subjects have an inversion of long term memory storage useful information which is integral for cognition and for the unit structure of storage.

The processing pathway for nine year old subjects was more direct as the messages of the learning task were linearly related to the intelligence quotient and to the level of cognition. Intelligence on the other hand was negatively related to the encoder (% CODE). The feedback control is probably internal and involved the encoder and short term memory chunking ($LTM:M^1$) effect. The double negative relationship between $LTM:M^1$ and % CODE with intelligence probably served as a feedback for the messages of behavior done in the learning task. A third pathway was found between the M unit of the dimension algorithm and the useful information (REAL:SS) of the long term memory storage. This was that a decrease in the REAL:SS would result in an increase of the M unit, and thus an increase in the level of cognition. Concomitantly, an increase size of the M unit would result in an increased encoder (% CODE), in turn decreasing the level of intellect and message processing, as well as level of cognition. It was concluded that intelligence was directly related to learning and cognition, but that the unit structure is involved by encoding control of the intelligence, both through learning levels and chunking effects.

The processing pathway for information flow by eleven year old subjects was found to be much like that of seven year olds. The major exceptions were the role of long term useful information (REAL:SS) both as a nonlinear operator for cognition and with the encoder (% CODE). The contrast was that the increase of encoding would have increased the amount of useful information stored in the long term memory. The major pathway seemed to be that an increase of intelligence would cause a decreased amount of long term memory useful information (REAL:SS). This effect would result in a larger inverse REAL:SS which was positively related to the level of cognition. The control feedback loop seemed to be between the REAL:SS, practice messages of learning, and encoding (% CODE) elements. The effect could be that an increase in the number of messages recorded in the learning task decreased the encoding (% CODE) and this tended to decrease the amount of REAL:SS per message processed. Again, the inverse of REAL:SS, being positively related to cognition, brought about the same result as found for the previously described pathway. As was found for the seven year old subjects, the inversion of long term memory useful information was integral for cognition and the effect of intelligence on cognition.

The most complex and seemingly confusing information processing linear operator pathway system was found for the 15 year old subjects. This was largely due to negative linear relationships existing for the short term chunking effect of the $\log_2$ of the inverse intelligence quotient and its negative relationship to the number of messages processed in the learning task. The cognition of the sorting task was obtained as a linear relationship only through the M unit algorithm and the initial recall of the message algorithm, which in turn was positively related to the long term memory storage of useful information (REAL:SS) per learning task message. As the number of messages increased, the short term memory chunking effect increased and this resulted in an increase of the storage of long term memory useful information (REAL:SS). In contrast there was an increase in the number of messages, the encoding ratio (% CODE) decreased, and there was a decreased size of the $\log_2$ inverse of intelligence quotient. The effect was a control feedback for an increase in the number of messages processed in the learning task. The conclusion was that the intelligence or schema structure was a logarithmically arranged unit on an inverse basis, and this case was integral for the influence of the amount of information stored in the long term memory.

The trend analysis just presented was extended to explore the unit structure of storage involved in the cognition levels obtained by subjects of different ages. The regression trend for changes of intelligence again showed the 15 year old group processed long term memory useful information (REAL:SS) differently than that done by younger groups of subjects. Consequently, the recall and M unit concept was inversely operating for increases in intelligence.

The discovery of the unique memory information flow for 15 year old subjects prompted two analyses. The first one was to propose the intelligence quotient is really a measurement of environment behaviors and that when considered as a memory process is logarithmic. The M unit was used to approximate the inverse base two logarithm of intelligence quotient for the trend analysis values of the age groups of subjects. The M increment of 0.0129 bit was used as a descriptor for differences between the M unit and inverse base two intelligence quotient logarithm. The results showed a distinct pattern by formal and concrete operation stages. The formal operation stage onset of 11 years had a range of eight M units with an average change of 1.83 units. On the other hand, the 15 year age was typified with little variance from a 3.12 M unit increment of 0.1548 bit. In contrast, and as found for forecasts of cognition by the dimension algorithm, the seven and nine year old groups of subjects had M value changes as great as that of 11 year olds, but averaged less than one increment value.

The plausibility of the analysis of intelligence being logarithmically structured in the human memory was found in two results of the M unit comparison. The 100 intelligence quotient level distinguished age groups of the concrete operational stage from the formal stage. The concrete age groups were at zero M increment, or approximating a unit structure of 0.1548 bit, whereas the formal stage groups had 2.4 and 3.5 increment increases beyond the .1548 bit unit. Thus at the average intelligence level a concrete figural sorting task involved no structural change of information stored in the memory of concrete operational stage subjects. Keeping in mind that cognition was approximated by the M unit treatment, cognition levels increased from 9.45 points to 15.66 points for the 15 year old group of subjects.

The second result giving evidence for the relationship of a logarithmic intelligence fashion in the memory is the shift of M values as intelligence approaches what is regarded as "above-average". The shift began at the 120 intelligence quotient level and the trend was for more increment M values to be attributed to the concrete level groups of subjects. The 170 level of intelligence quotient showed the previously mentioned pattern of 7, 11 year and 9, 15 year groupings of subjects.

The second test of the plausibility for the concept of a logarithmically "arranged" intelligence in the human memory was to do a computer construction of equations to forecast the cognition level of age groups of subjects at a trend level of intelligence. The algorithm elements were limited to the encoding process and long term memory useful information measures and the set elements hypothetically written in the learning task. The finding was that, with a limit of three equation construction attempts, the program developed equations which were not of a largely random selection and predicted the 20 cognition levels by an error of less than three and one-half percent. The pattern of equations strongly indicated older subjects, aged 15 years, had more uncommon information pathways involving transformations of intelligence and long term memory storage.

It seems that intelligence, as defined by standardized instruments, is a manifestation of environment processing representations by humans. This research report indicates that linear operator kinds of information processing involve intelligence in different ways, depending on the age of the human. As the experimental task was of figural symbols, the conclusion should be limited to how humans process a visual field into set formations of symbol signs and then reproduces it on another visual field in a recall task. It is obvious that the learning task involved the passage of information into the eyes of the human, through the brain, and thence onto a piece of paper whereon were placed numbers identifying elements of a classification type of set of figures with properties of shape, color and location on the visual display.

The fact that the information measures were calculated from the set formations means the information described the product of a memory processing of visually received information, of the ordinary sense. Obviously then, when these information measures statistically predict a later recall, the information is of that treated by the human memory. This history of events can be an explanation of the applicability of transformations of information measures and intelligence (such as to a base two logarithm) to data interpretations. The same inference may be drawn to the corresponding plausibility of the dimension algorithm for forecasting cognition.

This report is the first one to establish descriptions of the role of intelligence and information processing by humans aged seven to fifteen years in learning and cognition task. It could serve as a landmark study for changing the course of science learning research: to one recognizing humans process intelligence-related memory information in learning and cognition tasks.

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